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Peeling Back the Layers:
The Material Life of Girl with a Pearl Earring

Sara Belasco

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Honor Thesis

Peeling Back the Layers: The Material Life of *Girl with a Pearl Earring*
By Sara Belasco

Introduction

During this semester-long project I researched Johannes Vermeer's *Girl with a Pearl Earring* (1665), with three goals in mind: to examine the materials, techniques, aging, and conservation of the painting; create a copy of the painting; and write about my findings. First, I researched the artistic techniques and materials used in the painting, as well as the aging and degradation of these materials and previous conservation treatments, to understand the painting's current aesthetic state and how it has changed since it leaving Vermeer's studio over three hundred years ago. Second, I synthesized this information to create a copy of the painting and reenact Vermeer's painting technique, allowing me to gain a more comprehensive and in-depth understanding unachievable through other means. Third, using *Girl with a Pearl Earring* as a case study, I explored how research achieved through conservation benefits art historical discourse.

Girl with a Pearl Earring, one of Vermeer's most famous paintings, was completed in 1665 (Image 1).¹ Pieter van Ruijven, Lord of Spaland and a wealthy investor in Delft, purchased the painting directly from the artist. Van Ruijven did not commission the painting, though he did often have first pick on paintings coming out of Vermeer's studio. Vermeer sold two to three paintings per year, selling them not on the open market, but for a few regular clients. A regular lower- or middle-class person could not have bought a Vermeer; there would have been no opportunity to browse his paintings without an invitation or a connection.

Girl with a Pearl Earring represents the Dutch category of *tronie*, as evident in the clothing worn by the girl. The term *tronie* refers to heads, faces, or expressions and is commonly employed

¹ *Girl with a Pearl Earring* (44cm x 39 cm) was attributed to Vermeer in 1881. In 1903 the painting came into the possession of the Royal Cabinet of Paintings Mauritshuis as part of a bequest by A.A. Des Tombe of a total of twelve pictures.

to describe a type of picture created by Rembrandt and his followers. As Walter Liedtke explains, artists fabricated varied facial types, expressions, textures and light effects, poses, and imagined personalities, allowing *tronies* to exhibit a wider diversity than portraiture. The majority of Dutch *tronies* were based on live models but the works were sold as studies of invented exotic characters.² While the girl's jacket is a contemporary garment, probably made of wool with long, inset sleeves with cartridge pleating that were fashionable in the 1660s, the turban and very large pearl make this painting a *tronie*.³ A typical Dutch girl would not wear these items on a regular basis, and they mark her as an exotic figure.⁴ Vermeer painted three other *tronies*, each identifiable by their unusual clothing. The characters represented in *Girl with a Red Hat* (1665-67) and *Girl with a Flute* (1665-70) share the same open-mouthed expression of slight surprise as the figure in *Girl with a Pearl Earring*, creating a voyeuristic situation in which the viewer or Vermeer himself disturbed these women by accident, intruding on their private moments (Images 2 and 3).⁵

Artistic Technique and Materials

Before a seventeenth-century painter could start painting, he had to go through four steps to prepare the support. *Girl with a Pearl Earring* was painted on a linen canvas support, which artists could purchase stretched and ready made. Linen canvas was widely produced in the Netherlands for the manufacture of a variety of goods, notably ship sails, and explains its ease of

² Walter Liedtke, *Vermeer: The Complete Paintings* (New York: Abrams, 2008), 131-32.

³ Quentin Buvelot, ed., *Portraits in the Mauritshuis: 1430-1790* (Zwolle: Waanders Publishers, 2004), 259.

⁴ Lea Van der Vinde, ed., *Girl with a Pearl Earring: Dutch Paintings from the Mauritshuis* (San Francisco, CA: Fine Arts Museums of San Francisco, 2013), 43.

⁵ The third *tronie* by Vermeer is *Study of a Young Woman* (1665-67) in the Metropolitan Museum of Art, New York. Here the young woman also wears a similar headdress and earring as the girl in *Girl with a Pearl Earring*, but her face does not evoke the same idealized beauty.

purchase.⁶ The first step after procuring a canvas was to prepare it for the paint layers by applying a ground made of chalk or gesso bound in an aqueous medium, preventing the next layer from bleeding through the canvas. Then an *imprimatura*, pigments bound in an oil medium, was applied over the ground layer to prevent subsequent paint layers from absorbing into the ground.⁷ For *Girl with a Pearl Earring*, Vermeer used a mixture of lead white, ivory black, and a little red and brown ochers to create a cool, light grey color applied with the curving movements of a large priming knife.⁸

After the canvas was prepared, the artist could start gradually building up the paint layers. First, Vermeer executed an underdrawing, possibly with a very thin layer of yellow ocher paint; from the second quarter of the seventeenth century onward it was not unusual to sketch the composition in a light ocher.⁹ Then Vermeer painted an undermodeling, or dead coloring, to block in light and dark areas. Vermeer painted each area of the underpainting for *Girl with a Pearl Earring* with a different color, instead of using a monochromatic palette (Refer to Appendix A for pigments used for each area in each layer of the painting). The undermodeling was painted a different color than what the artist intended for the final product. For example, a charcoal black undermodeling was used in the girl's jacket, a darker tone than the final layer, making the yellow-hued layer over it appear a greenish color by exploiting the transparency of the medium to create

⁶ Epcó Runia, *Preserving Our Heritage: Conservation, Restoration, and Technical Research in the Mauritshuis* (Zwolle: Waanders, 2009), 38.

⁷ Nico van Hout, "Meaning and Development of the Ground Layer in Seventeenth-Century Painting" in *Looking Through Paintings: The Study of Painting Techniques and Materials in Support of Art Historical Research*, ed. Erma Hermens (London: Archetype, 1998), 200.

⁸ Runia, *Preserving Our Heritage*, 184.

⁹ Jorgen Wadum, *Vermeer Illuminated: Conservation, Restoration and Research: A Report on the Restoration of the View of Delft and the Girl with a Pearl Earring* (The Hague, Netherlands: V+K Publishing/Inmerc, 1995), 11.

optical mixing.¹⁰ In the light areas, a thin layer of dark underpaint was used, and in the dark areas a thicker layer of dark paint was used.¹¹

Once the underpainting was completed and dry, Vermeer applied the main paint layer using a wet-into-wet technique; he used warm hues and translucent layers in dark areas, such as the shadows of the girl's face and jacket, to allow the undermodelling to shimmer through and cool hues and opaque layers in the light areas, such as the where the light shines on the girl's face and turban.¹² Seventeenth-century artists painted sequentially, area by area, not all at once.¹³ To create a natural blurring of boundaries, as seen especially in the boundary between the girl's face and the background, Vermeer let areas of paint slightly overlap at the transitions along contours and let a little bit of the *imprimatura* color show between a figure's contour and the background. He also scumbled thin layers of paint over the edges.¹⁴ Scumbling, done over a coat of paint that has become dry to the touch, refers to the use of thinly applied transparent colors of a lighter value over a transparent or opaque layer of a darker value. The paint may be applied with a brush and the excess paint wiped off with a rag, leaving a uniform coating of the desired tone, or it may be stippled or rubbed on with a brush, dabber, rag, or fingers.¹⁵

After the main wet-in-wet paint layer dried, Vermeer added details to complete the painting. In the girl's face, half tones were formed with a scumble containing ochre. The pearl was

¹⁰ Nicola Costaras, "A Study of the Materials and Techniques of Johannes Vermeer" in *Vermeer Studies*, ed. Ivan Gaskell et al. (New Haven: Yale University Press, 1998), 155.

¹¹ Groen, Van der Werf, Jan van Den Berg and Boon, "Scientific Examination of Vermeer's *Girl with a Pearl Earring*," 171.

¹² Buvelot, *Portraits in the Mauritshuis*, 262.

¹³ Ernst van de Wetering, "Reflections on the Relationship between Technique and Style: The Use of the Palette by the Seventeenth-Century Painter," in *Historical Painting Techniques, Materials, and Studio Practice: Preprints of a Symposium, University of Leiden, the Netherlands, 26-29 June, 1995*, ed. Erma Hermens et al. (Marina Del Ray, CA: Getty Conservation Institute, 1995), 201.

¹⁴ Liedtke, *Vermeer*, 48.

¹⁵ Ralph Mayer, *The Artist's Handbook of Materials and Techniques* (New York: Viking, 1991), 248.

not painted in the wet-in-wet stage, but was added afterwards also using a scumbling technique with whitish paint and an opaque highlight where the pearl reflects the girl's white collar. A light pink glaze was added to areas of the face, and a green glaze made of indigo and weld was applied to the background.¹⁶ A glaze generally refers to a thin, transparent layer of oil color of a darker value applied over an opaque or transparent layer of oil color of a lighter value. Since the two layers are not mixed directly, the color of the underlayer blends with that of the transparent glaze because of optical effects.¹⁷ For glazing, the medium and the oil color should be mixed into a well-pigmented semifluid consistency and made into a thin layer after it has been applied to the canvas by stippling or tamping it with clean, dry brushes, rather than making it a thin-flowing underpigmented wash which will drip and go on unevenly.¹⁸

When the painting was finally completed and dry, the artist would apply a layer of varnish, which protected the paint film from minor superficial damage and moisture while also providing gloss, depth, and saturation of the paint colors. In the past, varnishes were made of natural resins, usually originating from trees. Common varnishes in the seventeenth century were mastic, colophony, and sandarac dissolved in a volatile solvent and sometimes mixed with oil. It is impossible to know exactly what varnish Vermeer originally used on his painting. Since natural resins turn yellow and opaque over time, they need to be removed and replaced, so the original varnish no longer remains on *Girl with a Pearl Earring*.¹⁹

¹⁶ Buvelot, *Portraits in the Mauritshuis*, 262.

¹⁷ Mayer, *The Artist's Handbook of Materials and Techniques*, 247.

¹⁸ Ibid, 249.

¹⁹ Runia, *Preserving Our Heritage*, 45.

Execution of the Copy

Before starting my copy, I had to decide what reproduction to use as my reference. While reproductions are important for the spread of art education and visual literacy, each reproduction of a painting differs slightly, especially colors and the compression of shadows. I used as my reference a professional poster I bought at The Frick Collection when I saw *Girl with a Pearl Earring* there in the *Vermeer, Rembrandt, and Hals: Masterpieces of Dutch Painting from the Mauritshuis* exhibition (Image 4). No reproduction portrays a completely accurate depiction of the painting as seen in real life, therefore my copy is a step removed from the original painting.

I set up my studio wall with inspirational images of other works by Vermeer and details of *Girl with a Pearl Earring* (Image 5). Underneath the poster of *Girl with a Pearl Earring*, I placed a picture of the painting before its 1994 conservation treatment so that I could keep in mind the aesthetic changes the painting has gone through. Enlarged images of the top of the girl's turban, her face, and her jacket hang next to the reproduction on which I circled areas and mapped out where certain pigments and techniques were (Image 6). Next to these images I put print-outs of other paintings by Vermeer that shared similarities with *Girl with a Pearl Earring*, such as yellow fabric, facial expression, and *pointille* highlights.

Since Vermeer used a pre-stretched ready made canvas, I purchased a Fredrix Pro Linen stretched canvas made of Belgian linen and primed with acid-free acrylic Titanium white gesso. I applied an *imprimatura* made of a mixture of titanium white, zinc white, red and brown ochers, and carbon black using a priming knife. After the *imprimatura* dried it seemed too dark and not neutral enough, possibly because there was too much red ocher (Image 7). I sanded the paint layer with 150 grit sand paper to remove some of the previous *imprimatura* and the second time I made

sure that the color I mixed was more cool and grey, as Runia Epco describes, and I used ivory black instead of carbon black because it is cooler (Image 8).²⁰

Executing the underdrawing was more difficult than expected because there are very few hard lines in *Girl with a Pearl Earring*. I painted the underdrawing in yellow ocher, diluting the paint with Livos Thinner (Image 9). Drawing the face was particularly difficult because it was entirely made up of shadows, which made sketching the eyes and nose very hard. I tried to block in some shadowed areas to create a sense of placement in the face, but overall it looked Picasso-esque with only geometric shapes for facial features. Also, the canvas used was not the same exact dimensions as *Girl with a Pearl Earring*, so the placement of the girl on the canvas did not precisely match up.²¹

For the underpainting I used a medium of 2/3 Livos and 1/3 stand oil (Image 10). Ivory black, a cooler black, was used in the background and turban, while carbon black, a warmer black, was used in the jacket. I painted background first, followed by the turban and jacket. Once these areas were dry I did the underpainting of the face so that the reds and creams would not become contaminated with black. The deep shadows of the cheek and neck were a reddish brown, made by mixing red ocher and ivory black, the shadows of the nose and mouth were red lake, red ocher, and vermilion, and the highlights were a mixture of titanium and zinc whites.

Since Vermeer painted sequentially, area by area and not all at once, I started painting the jacket first using a wet-in-wet technique using a medium of 1/3 stand oil, 1/3 dammar varnish and 1/3 Venetian turpentine (Image 11). The yellow ocher that I used was less red than what appeared in the reproduction, so I added a little red ocher even though Vermeer did not use it so that the copy would match my reference. To make the shadows I added indigo, red ocher, and black. The

²⁰ Runia, *Preserving Our Heritage*, 184.

²¹ The original *Girl with a Pearl Earring* measures 44 cm x 39 cm and my canvas is 61 cm x 46 cm.

highlights were yellow ochre and zinc and titanium whites. When I was almost finished with the jacket, I realized that the proportions were too wide, and so I had to repaint it (Image 12). The left edge of the jacket should have extended just slightly beyond the edge of the girl's cheek and the right edge should have ended just before the right edge of the first hanging fold in the turban.

I painted the turban using the same medium of stand oil, dammar varnish, and Venetian turpentine and ultramarine, yellow ochre, red ochre, lead and titanium whites, indigo, and azure blue (Image 13). The blue shadows of the turban were mainly azure blue with a little indigo, ultramarine, and black mixed in. Azure blue possesses a natural transparency, which combined with the added transparency of the medium worked significantly to my advantage in this area. The reference image has a lot of texture in the shadows, and the transparency allowed my brushstrokes from the underpainting to show through, adding that needed texture.

The same medium used for the turban and jacket was used when painting the girl's face, and I used zinc and titanium whites, yellow ochre, red ochre, and black pigments (Image 14). For the lips I used red ochre, vermilion, and madder lake. Painting the lips proved to be a challenge because red paint very easily spreads and contaminates other colors, so while blurring the boundary between the lips and skin I had to be very careful not to make the lips seem bigger and fuller than they are.

Once the face dried I painted the last remaining element, the pearl. I used a scumbling technique and titanium and zinc whites, ivory black, and red ochre. I decided not to apply a glaze of yellow lake and indigo in the background because the glaze in the original painting aged to look almost black instead of green, and in my reference image the background looked completely black.

Since I used an oil and dammar mix as my medium it is generally recommended to wait six months before varnishing. No concrete information exists on what varnish Vermeer used on his paintings, and so for my copy I will use a mixture of dammar resin varnish and Tinuvin 292, which conservators Jorgen Wadum and Petria Noble used during the 1994 restoration of *Girl with a Pearl Earring*. Dammar varnish yellows less over time than other varnishes, and further protects paint layers by absorbing UV radiation. Tinuvin 292 is a light stabilizer and when added in small concentrations slows varnish degradation. When mixing the varnish, Tinuvin 292 will be added at three percent of dammar's weight. Tinuvin 292 and resins in general are less stable as a liquid in solution than they are as a dried film, therefore mixtures should be made in small batches.²²

Aging of Materials and the Painting's Current Aesthetics

When deciding on how I wanted to execute my copy of *Girl with a Pearl Earring*, I had to decide what I wanted it to look like. Trying to paint a copy that looked exactly as if it had just left Vermeer's studio would have been impossible because the painting no longer looks the same as when it was completed over three hundred years ago. However, copying the painting exactly as it looks today would not be possible either because I could not accurately copy craquelure patterns, nor use exactly the same pigments. My copy describes the painting as it currently looks today to the best of my abilities, taking into account the materials' aging such as faded and discolored pigments.

Over time the materials in a painting degrade due to inherent problems, natural aging, or accidental damage. For example, canvases lose tension, begin to sag, become brittle, and can tear from the weight of the paint, usually along the edges where it is folded over the stretcher. To

²² Michael von der Goltz, "Contemporary Use of Dammar and Mastic Varnish," in *Conservation of Easel Paintings*, ed. Joyce Hill Stoner et al. (New York: Routledge, 2012), 642.

strengthen the canvas most seventeenth century paintings have been lined, providing them with a second canvas for additional support.²³

One major sign of aging in a painting is *craquelure*, the small cracks present throughout the paint layers of *Girl with a Pearl Earring*. The *craquelure* in the corners of the canvas are stress crackles, which developed when the stretcher keys were expanded with too much force (D in Image 15).²⁴ Canvas is impressionable to sharp blows or prolonged but gentle pressure, such as a piece of furniture leaning against the painting. A concentric pattern of circular cracks, like a spider web pattern, within an otherwise regular *craquelure* pattern is usually the result of stress or sudden impact (A in Image 15).²⁵ As the paint layers age and lose elasticity they become brittle. Minor humidity fluctuations also cause expansion and contraction of the canvas support, resulting in cracks in the paint layer (B in Image 15).²⁶ In *Girl with a Pearl Earring*, fine *craquelure* that formed in the ground layer shortly after it was applied can be seen (C in Image 15).²⁷

Pigments that contain a high proportion of oil to pigment are particularly liable to discoloration, such as red lake, all black pigments, some yellow ochers, and azurite.²⁸ Discoloration is also more likely to occur with pigments made from organic colorants. Organic pigments derive from vegetables (indigo, madder, weld), animals (carmine), and synthetic organic pigments. Inorganic pigments derive from native earths (ochers, green earth, ultramarine,) and inorganic synthetic colors (zinc oxide, vermilion).²⁹ To be used in a painting, most organic

²³ Runia, *Preserving Our Heritage*, 39.

²⁴ Ibid, 184.

²⁵ Andrea Kirsch and Rustin Levenson, *Seeing Through Paintings: Physical Examination in Art Historical Studies* (New Haven: Yale University Press, 2000), 155.

²⁶ Ibid, 152.

²⁷ Runia, *Preserving Our Heritage*, 184.

²⁸ Margriet van Eikema Hommes, *Changing Pictures: Discoloration in 15th-17th Century Oil Paintings* (London: Archetype, 2004), 19.

²⁹ Mayer, *The Artist's Handbook of Materials and Techniques*, 31.

pigments are first made into lake pigments, letting the colorant form a precipitate onto a white substrate, usually aluminum hydroxide. Other white substances such as chalk and other natural white earths were also used. The colorfastness of lake colors is extremely varied. Good carmine or madder lakes are reasonably light resistant, all yellow lakes have a mediocre to extremely poor colorfastness, and indigo rapidly fades in an oil medium when exposed to light.³⁰ For more information on the degradation of pigments see Appendix B. In *Girl with a Pearl Earring*, the most noticeable pigment discoloration is in the background, which used to be a greenish glaze of indigo and weld, which darkened significantly so that it currently looks only black.

Conservation History and the Painting's Current Aesthetics

Conservation refers to the steps taken to slow down the degradation process to ensure the survival of works of art, including climate control, making sure the objects are stored under optimum conditions, and restoration. The conservation treatment of an art object may involve some intervention in the structure of the object in order to improve its accessibility and aesthetic appeal, or for conservation reasons. Before conducting any conservation treatment, a thorough investigation of the materials of a work of art must be done, enabling the conservator to become familiar with the object and providing opportunities to identify problems and their methods of treatment.³¹

In 1915 and 1922 Derix de Wild, a conservator at the Mauritshuis, regenerated the varnish layers *Girl with a Pearl Earring*, jeopardizing the unstable paint layer (Image 16).³² The regeneration of blanched varnishes was generally achieved by exposing the surface of the painting

³⁰ Hommes, *Changing Pictures*, 28.

³¹ Wadum, *Vermeer Illuminated*, 16.

³² Groen, Van der Werf, Jan van Den Berg, and Boon, "Scientific Examination of Vermeer's *Girl with a Pearl Earring*," 170.

to alcohol vapors, but when oil varnishes were involved a combination of alcohol vapors and copaiba balsam were used.³³ Copaiba balsam causes softening, darkening, and swelling of the paint and migration of loose components. Flakes of original paint had stuck upside down to other parts of the painting, with the light ground facing up. For example, after this treatment the pearl earring had three light reflections; the third reflection was not original, but a loose flake of paint accidentally stuck to the spot during the varnish regeneration (Image 17).³⁴ The brownish-black material that exuded from cracks in the forehead and cheek of the girl before the 1994 restoration was copaiba balsam also from de Wild's intervention (Image 18).³⁵

Girl with a Pearl Earring was relined in 1882 and 1960, causing permanent damage to the paint layer. When a canvas is so weak that it can no longer fully support the ground and paint layers, a new canvas is affixed to the back of the original one as a physical support.³⁶ The lining process involves adhesive applied with pressure and heat, which can affect the look of a painting.³⁷ Vermeer used an impasto technique to emphasize the effect of different fabrics as seen in the yellow of the turban, the highlights of the pearl, and in the yellow dots on the jacket. These accents, however, were flattened when the painting was lined (Image 19). In 1882 a starch paste was used as an adhesive for the lining, evidenced by the shrinkage of the original canvas due to contact with water.³⁸ In 1960 *Girl with a Pearl Earring* was lined with a wax-resin mixture onto a fine linen cloth with a close weave. The original canvas was fully impregnated by the wax-resin mixture. The remaining tacking edges were folded outward, making the painting larger than it used to be.³⁹

³³ Ibid, 176.

³⁴ Ibid, 25.

³⁵ Ibid, 177.

³⁶ Kirsch and Levenson, *Seeing Through Paintings*, 33.

³⁷ Ibid, 38.

³⁸ Runia, *Preserving Our Heritage*, 185.

³⁹ Wadum, *Vermeer Illuminated*, 18.

During the 1994 restoration, *Girl with a Pearl Earring* was cleaned using a mixture of solvents that would remove only the discolored varnish layer and not any of the original paint. After cleaning, little dots of light emerged, characteristic of Vermeer's *pointille* technique, such as the small light reflection near the left corner of the girl's mouth and on the girl's jacket (Images 20 and 21).⁴⁰ Also during this treatment, it was discovered that the third reflection on the pearl earring was a loose fragment of paint that had migrated during the 1922 restoration.⁴¹

Before the 1994 restoration of *Girl with a Pearl Earring*, many discolored retouches were present from past conservation treatments, which needed to be removed (Image 22). A retouching is the reintegration of missing or damaged paint layers to a state that is consistent with the remaining original.⁴² However, before a conservator decides to follow contemporary tastes by removing and destroying any additions, all alterations should be studied and documented. Additions or alterations carried out by the original artist—*pentimenti*—should never be removed because they are original documents representing the artist. Additionally, any later additions or alterations to an original painting may have historical values themselves.⁴³ Additions are part of the painting's history and authenticity, which are not reproducible because they are interconnected with the life history of the painting. Additions may demonstrate the relationship of a painting to a given moment of time. The painting will embody contemporary cultural, social, and aesthetic influences.⁴⁴

⁴⁰ Ibid, 23.

⁴¹ Ibid, 25.

⁴² Shawn Digney-Peer, Karen Thomas, Roy Perry, Joyce Townsend, and Stephen Gritt, "The Imitative Retouching of Easel Paintings," in *The Conservation of Easel Paintings* ed. Joyce Hill Stoner et al. (New York: Routledge, 2012), 607.

⁴³ Michael van der Goltz, and Joyce Hill Stone, "Considerations on Removing or Retaining Overpainted Additions and Alterations," in *The Conservation of Easel Paintings* ed. Joyce Hill Stoner et al. New York: Routledge, 2012), 497.

⁴⁴ Ibid, 498.

Cases do exist where overpaint should be removed or altered, for example, any overpaint covering the artist's original paint should be removed in order to bring the appearance of the painting close to its presumed original state, or if it hinders further conservation treatments. If the overpaint does not cover or harm the original, but is aesthetically inappropriate, it may be retouched so that it is no longer visible in natural light, but is discernable under examination with ultraviolet light. This approach has the advantage of following the conservation ethical guideline of reversibility and at the same time retaining the historical information should the alteration need to be researched or revealed in the future.⁴⁵

In the same way that later additions to the original painting must be removed, retouching undertaken during a current conservation treatment must also take care not to alter or conceal the original paint. The purpose of retouching is not to make the painting look new, but to restore visual harmony and readability. Retouching must be performed as objectively as possible with no attempt to misrepresent the artist's intent regarding to the known aesthetic, conceptual, and physical characteristics of the painting.⁴⁶ It is important that all retouching materials used are unreactive towards the original, removable from the original at any time without harming it, and reasonably stable and unlikely to alter over time to ensure maximum duration of restoration.⁴⁷

During the 1994 restoration of *Girl with a Pearl Earring*, some old retouches were removed together with the varnish while others were more difficult to dissolve. These retouches were first thinned by scraping with a surgical scalpel, leaving only a thin residue. Then they were removed by dissolving the layer of varnish below the hard retouches with a solvent, releasing them from the outer edges inward. The binding medium of the old, insoluble retouches was analyzed by

⁴⁵ Ibid, 499.

⁴⁶ Digney-Peer, Thomas, Perry, Townsend and Gritt, "The Imitative Retouching of Easel Paintings," 608.

⁴⁷ Ibid, 613.

gas chromatography, indicating components typical of old, dried linseed oil. This explained why it was so difficult to remove the retouches with the selected solvent, which was formulated to remove varnish and not oils.⁴⁸

The new retouches were made by underpainting in watercolor with a transparent glaze of dry pigment mixed with a synthetic resin. Unlike the old oil paint retouches, these paints will show little or no discoloration in the future. The watercolor paint and pigments are light-fast and the binding medium, a synthetic resin, is also extremely stable. To complete the restoration process, a colorless dammar resin varnish with Tinuvin 292 added as a stabilizer to retard ageing and yellowing was applied to obtain a uniform gloss and to protect the surface of the painting and the new retouches.⁴⁹

How Conservation Contributes to Art Historical Knowledge

Technical examination of a painting through conservation can provide information for a number of questions. Specifically, technical examination can help with doubts of authenticity or attributions. Looking at the brushwork and layering of the paint layers can show if the painting corresponds to other works by the same artist, whether multiple artists collaborated on the painting, or any compositional changes related to known sketches, other paintings, historical information, or photographic records.⁵⁰

An investigation of the materials and techniques yields information about the painting's condition. We can see how much the work presently resembles the one that left the artist's studio or how much it has changed through aging processes, and these studies provide information

⁴⁸ Wadum, *Vermeer Illuminated*, 22.

⁴⁹ Ibid, 28.

⁵⁰ Kirsch and Levenson, *Seeing Through Paintings*, 101.

related to dating, provenance, and the interpretation of the work.⁵¹ One major method of analysis for the aging of materials is pigment analysis, which reveals colors that have changed over time. X-ray fluorescence can provide information about the various chemical elements present in specific areas of a painting; chemicals are almost always pigment specific, so their identification can provide information about the artist's buildup of paint layers.⁵² Paint samples can also be used for identification, but this technique destroys the sample so it is used only in extreme circumstances or if a piece of paint is already loose. Tiny paint samples are used to make cross-sections, which can be analyzed under a microscope. The sample is embedded in a plastic resin and then ground to reveal the structure of the paint layer so that the thickness of the paint and varnish layers as well as the type of pigments can be determined.⁵³

A second method to determine aging is UV fluorescence. Each substance in a painting fluoresces differently, and UV light can be used to reveal details on the surface of the painting. For example, old varnishes often have a greenish fluoresce, but later overpainting and retouches applied onto the original paint or onto the varnish interfere with the fluorescence and cause dark areas. Using this technique, conservators were able to distinguish between old retouches on *Girl with a Pearl Earring* and the original paint before cleaning the painting (Image 22).⁵⁴

Conservation research and procedures have greatly influenced the art historical knowledge of *Girl with a Pearl Earring*. For example, a good deal of discourse surrounding Vermeer's preparatory layers had existed concerning whether he used a charcoal underdrawing or no drawing

⁵¹ Van Loon, Noble, and Burstock, "Ageing and Deterioration of Traditional Oil and Tempera Paints" in *The Conservation of Easel Paintings*, ed. Joyce Hill Stoner et al. (New York: Routledge, 2012), 215.

⁵² Arthur K. Wheelock Jr., *Vermeer and the Art of Painting* (New Haven: Yale University Press, 1995), 11.

⁵³ Wadum, *Vermeer Illuminated*, 16.

⁵⁴ Ibid, 21.

at all. Examination under a stereomicroscope during the 1994 conservation treatment revealed some paint strokes in a light ochre color on the *imprimatura* at the edge of the girl's face, which may be an underdrawing in paint.⁵⁵ X-radiography allowed conservators to see that the ground was applied with a knife rather than a brush because of marks made by the knife seen in the image.⁵⁶

Cleaning revealed two very important characteristics of Vermeer's style. First, as stated in the previous section, the pearl earring was thought to have three reflections: a large, teardrop-shaped highlight on the left of the pearl that reflects the light hitting the face from the top left, a reflection on the bottom of the pearl from the white collar of the girl's blouse, and a small, bright highlight on top of the latter highlight. After cleaning, it was revealed that this third highlight was not originally part of the painting and the true optical nature of the pearl was realized.⁵⁷ Second, the *pointille* highlights present on the girl's jacket, on the side of her mouth, and on the light part of her turban were uncovered during cleaning, possibly bolstering the claim that Vermeer used a camera obscura (Image 21). Vermeer may have used a camera obscura to observe its aesthetic values, such as the small points of light they reflected on objects, but not directly used it.⁵⁸

If art historians ignore the material aspects of paintings, they exclude a whole field of information vital for a complete understanding of the work and the artist. Some scholars have argued that examining art history from a technical point of view is purely a form of deconstruction

⁵⁵ Ibid, 11.

⁵⁶ Groen, Van der Werf, Jan van Den Berg, and Boon, "Scientific Examination of Vermeer's *Girl with a Pearl Earring*," 170.

⁵⁷ Wadum, *Vermeer Illuminated*, 24.

⁵⁸ Khar, *Dutch Painting in the Seventeenth Century*, 276. It is unclear as to whether Vermeer used a camera obscura or not because the camera obscura leaves no physical trace on the painting. The only way to determine whether or not Vermeer used the device is to determine if his paintings contain comparable optical characteristics. This argument is tangential to my paper topic, and so will not be explored in depth. For further reading on this subject see Arthur K. Wheelock Jr., *Vermeer and the Art of Painting* (New Haven: Yale University Press, 1995); and Phillip Steadman, *Vermeer's Camera: Uncovering the Truth Behind the Masterpieces* (Oxford: Oxford University Press, 2001).

that dismantles the object in isolation of any other factors. However, it can also celebrate the artistic process.⁵⁹ Conservators can help art historians achieve a closer understanding of the practical aspects of works of art, leading to a multidisciplinary collaboration in both fields; conservators and art historians should be concerned with what goes on in the other's field. Similarly to conservators, art historians as curators are guardians of cultural property.⁶⁰

⁵⁹ David Bomford, "Introduction" in *Looking Through Paintings: The Study of Painting Techniques and Materials in Support of Art Historical Research*, edited by Erma Hermens (London: Archetype, 1998), 12.

⁶⁰ John Leighton, "Taking a Closer Look: Art Historians, Restorers, and Scientists," in *Looking Through Paintings: The Study of Painting Techniques and Materials in Support of Art Historical Research* ed., Erma Hermens (London: Archetype, 1998), 31.



Image 1. Johannes Vermeer, *Girl with a Pearl Earring* (1665), oil on canvas, 44.5 x 39 cm.
Mauritshuis, The Royal Picture Gallery.



Image 2. Johannes Vermeer, *Girl with the Red Hat* (1665-7), oil on panel, 22.8 x 18 cm. National Gallery of Art, Washington, D.C.



Image 3. Johannes Vermeer, *Young Girl with a Flute* (1665-70), oil on oak panel, 20 x 17.8 cm.
National Gallery of Art, Washington, D.C.



Image 4. Reference image purchased at the Frick Collection.



Image 5. Inspiration wall in my studio space.

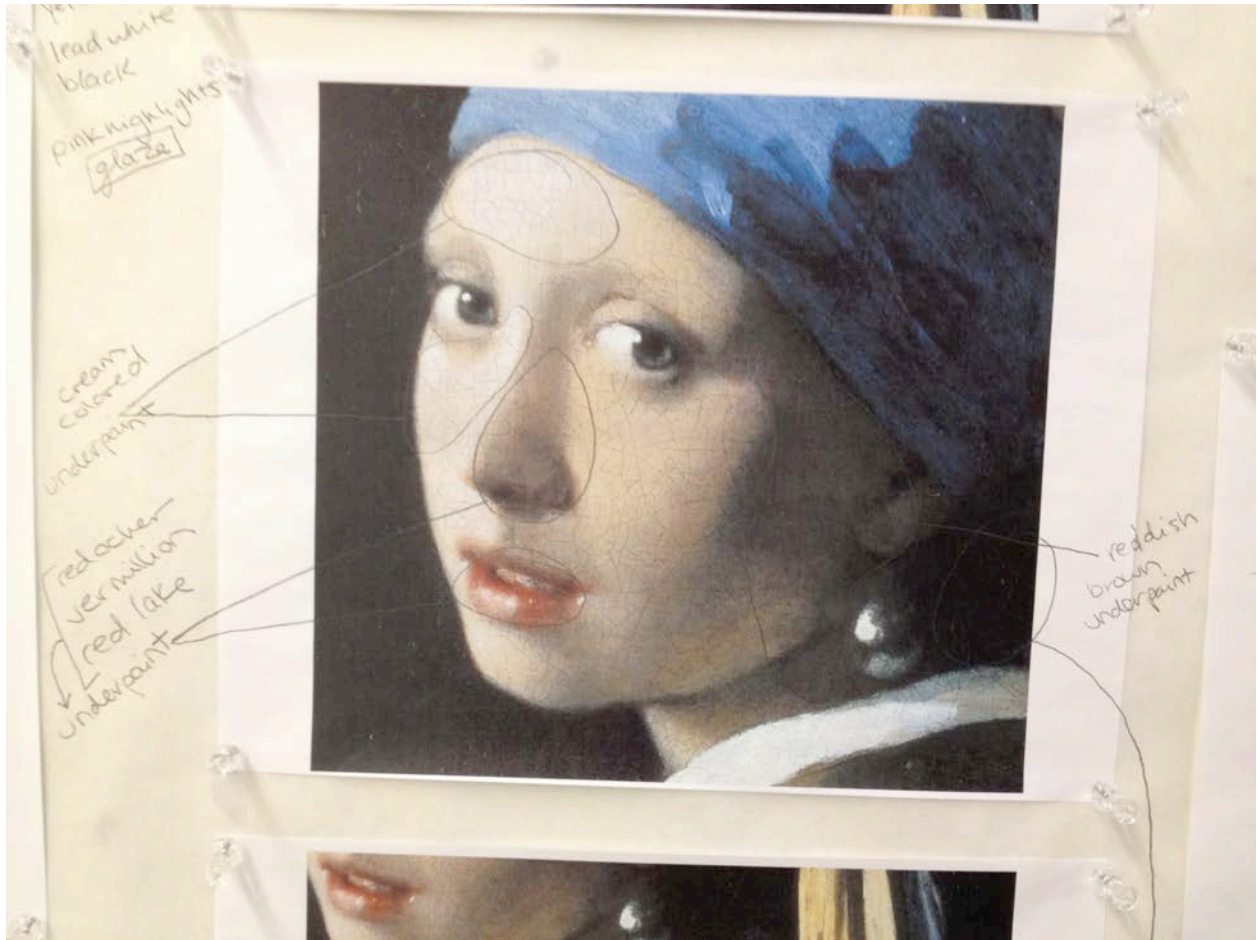


Image 6. On the inspiration wall I mapped out where certain pigments and techniques were, circling and labeling specific areas.



Image 7. First *imprimatura*, which was too warm.



Image 8. Second *imprimatura*, more cool.



Image 9. Underdrawing in yellow ochre.



Image 10. Underpainting



Image 11. Main paint layer for the jacket, which was too wide



Image 12. Main paint layer for the jacket after correcting the width



Image 13. Main paint layer after completing the turban



Image 14. Completed painting

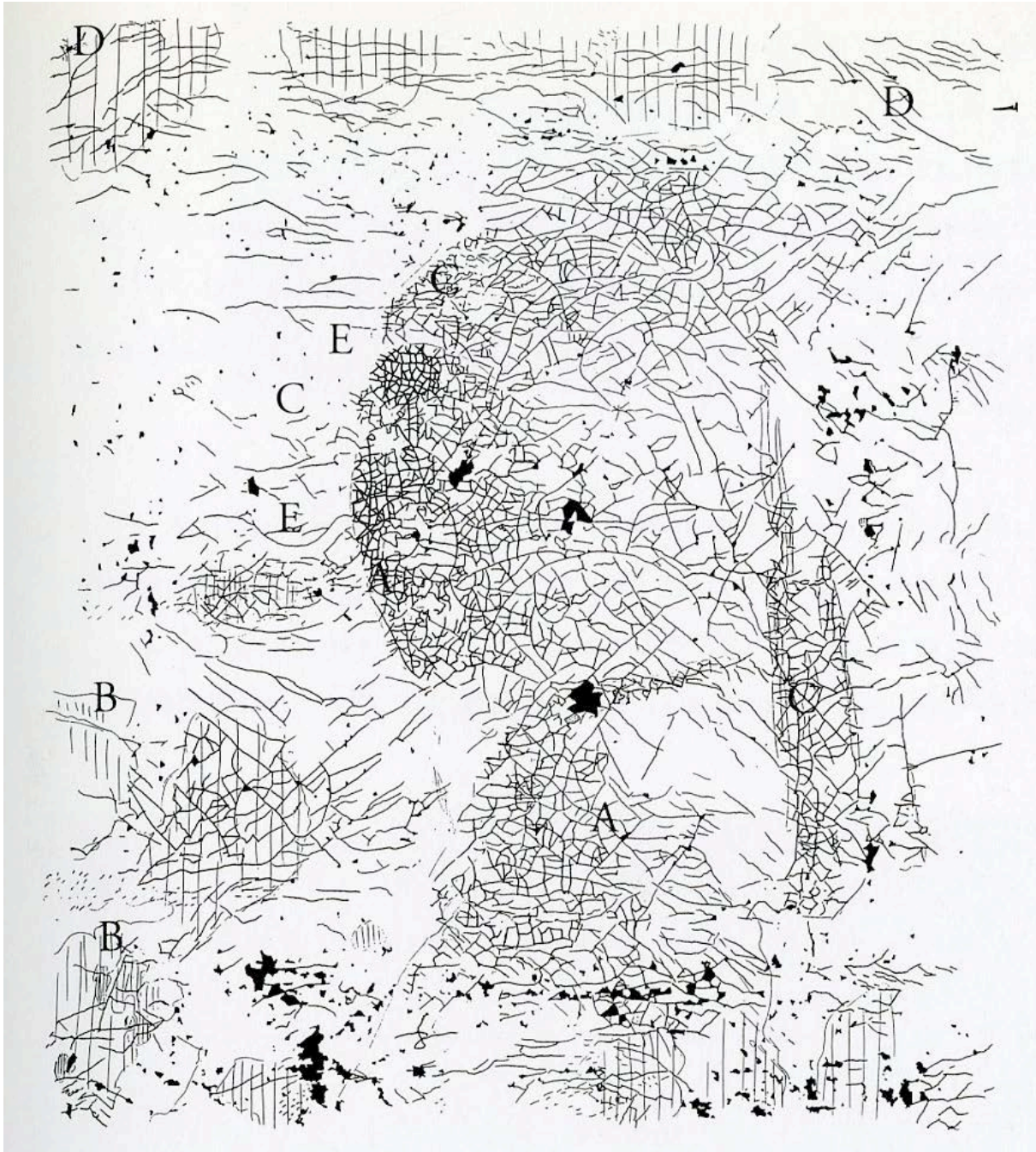


Image 15. Diagram of the different kinds of craquelure in *Girl with a Pearl Earring*. Originally in *Vermeer Illuminated: Conservation, Restoration and Research* by Jorgen Wadum (The Hague, Netherlands: V+K Publishing/Inmerc, 1995), 21.

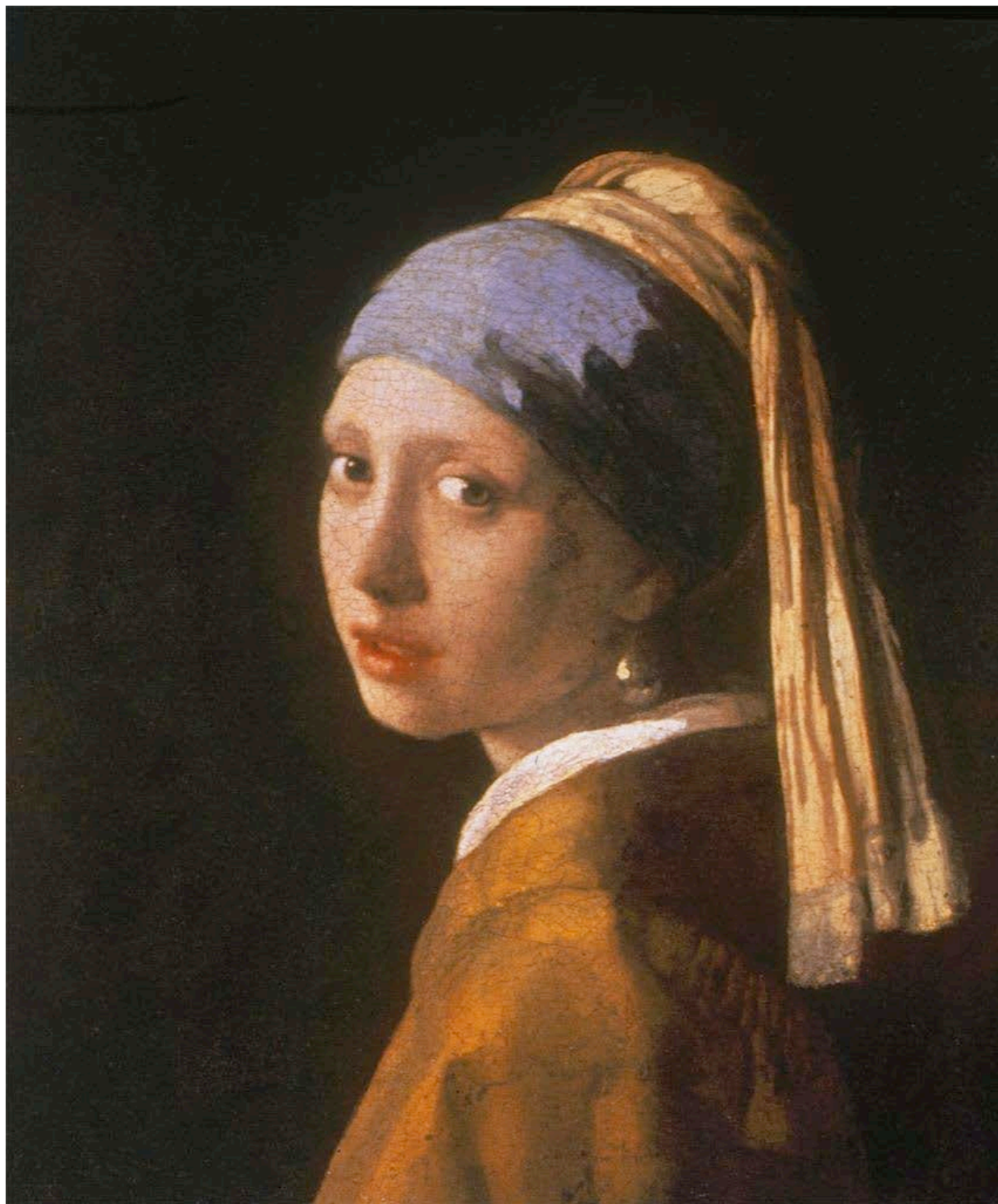


Image 16. *Girl with a Pearl Earring* before conservation in 1994.

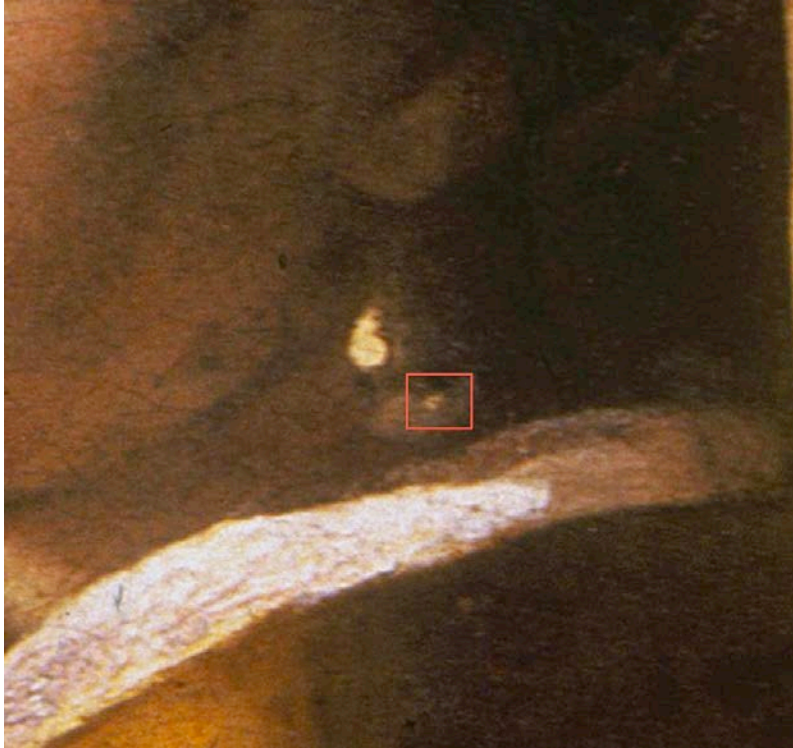


Image 17. Detail of the earring. The extra reflection that is actually a migrated flake of paint is in the red box.

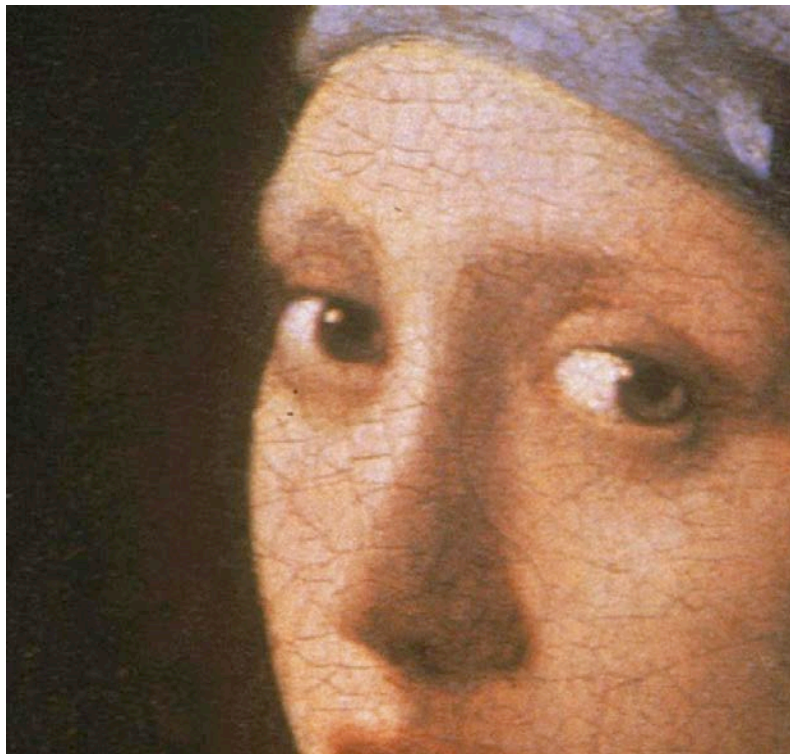


Image 18. Darkened *craquelure* in the forehead and cheek caused by copaiba balsam.



Image 19. Detail of the girl's collar, taken with raking light so that the texture of the flattened impasto from relining could be seen. Originally in *Vermeer Illuminated: Conservation, Restoration and Research* by Jorgen Wadum (The Hague, Netherlands: V+K Publishing/Inmerc, 1995), 26.

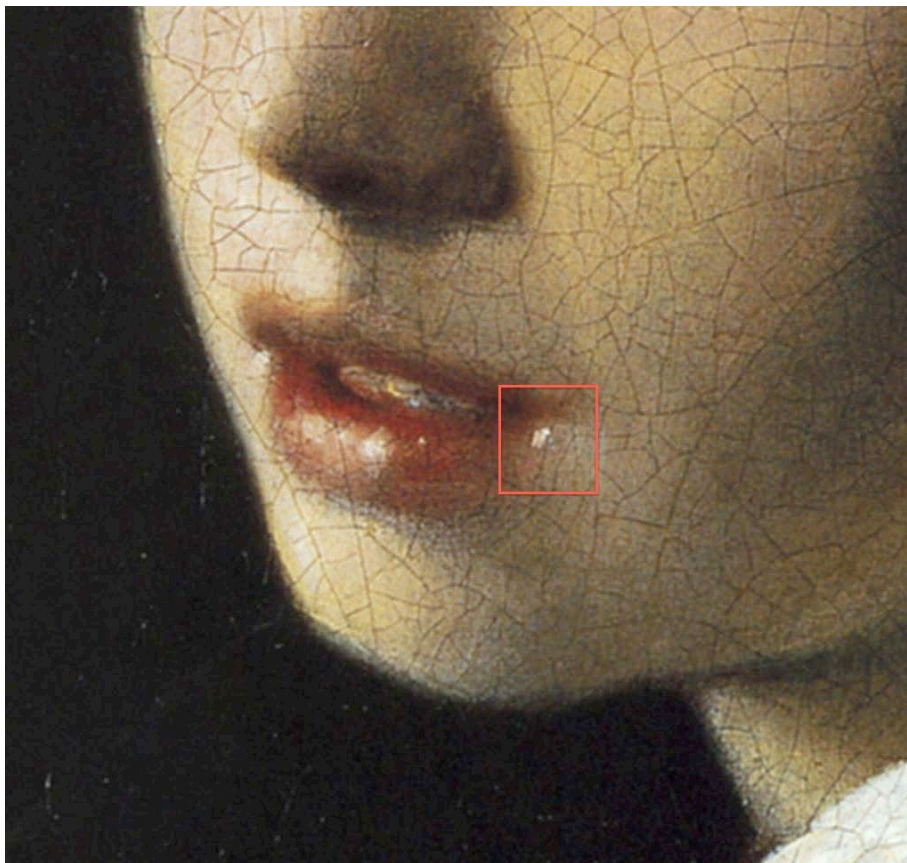


Image 20. *Pointille* highlight revealed after cleaning.



Image 21. *Pointillé* highlights revealed after cleaning.



Image 22. UV photograph. The dark areas are old retouches. Originally in *Vermeer Illuminated: Conservation, Restoration and Research* by Jorgen Wadum (The Hague, Netherlands: V+K Publishing/Inmerc, 1995), 20.

Appendix A: *Girl with a Pearl Earring* Pigments and Techniques Layer by Layer⁶¹

| Area of Painting | Ground | Under-drawing | Dead coloring/ Under-painting | Second Paint Layer | Scumbling | Glazing | Varnish |
|------------------|---|----------------------------|---|---|--|---------------------------------|--|
| Face | Lead white, bone black, red ocher, brown ocher applied with a priming knife ⁶² | Yellow ocher ⁶³ | Deep shadows of the cheek and neck are reddish brown, the shadows of the nose and mouth are red lake, red ocher, and vermilion, highlights are creamy white ⁶⁴ | Yellow ocher, lead white, black applied wet-into-wet ⁶⁵ | Scumble containing ocher ⁶⁶ | Madder, vermilion ⁶⁷ | Possibly mastic, colophony or sandarac ⁶⁸ |
| Turban | | | Bone black ⁶⁹ | Ultramarine, yellow ocher, organic red, lead white, indigo in the tail applied wet-into-wet ⁷⁰ | None | None | |

⁶¹ This table is a compilation of information from various sources organized in my own original format.

⁶² Runia, *Preserving Our Heritage*, 184.

⁶³ Wadum, *Vermeer Illuminated*, 11.

⁶⁴ Costaras, "A Study of the Materials and Techniques of Johannes Vermeer," 159.

⁶⁵ Buvelot, *Portraits in the Mauritshuis*, 262.

⁶⁶ Ibid, 262.

⁶⁷ Costaras, "A Study of the Materials and Techniques of Johannes Vermeer," 159.

⁶⁸ Runia, *Preserving Our Heritage*, 45.

⁶⁹ Wadum, *Vermeer Illuminated*, 13.

⁷⁰ Liedtke, *Vermeer*, 131; Costaras, "A Study of the Materials and Techniques of Johannes Vermeer," 158.

| Area of Painting | Ground | Under-drawing | Dead coloring/ Under-painting | Second Paint Layer | Scumbling | Glazing | Varnish |
|-------------------|---|---------------|----------------------------------|--|---|--------------------------------------|--|
| Jacket | Lead white, bone black, red ocher, brown ocher applied with a priming knife | Yellow ocher | Charcoal black ⁷¹ | Lead white, yellow ocher, ultramarine, indigo applied wet-into-wet ⁷² | None | None | Possibly mastic, colophony or sandarac |
| Pearl | | | None | None | Thin, whitish scumble and an opaque highlight ⁷³ | None | |
| Background | | | Bone black ⁷⁴ | None | None | Yellow lake and indigo ⁷⁵ | |

Appendix B: Aging in Pigments Used in the Original *Girl with a Pearl Earring*⁷⁶

⁷¹Groen, Van der Werf, Jan van Den Berg, and Boon, “Scientific Examination of Vermeer’s *Girl with a Pearl Earring*,” 172.

⁷²Ibid, 172.

⁷³Buvelot, *Portraits in the Mauritshuis*, 262

⁷⁴Ibid, 262.

⁷⁵Ibid, 262.

⁷⁶This table is an abbreviated adaptation from Annelies van Loon, Petria Noble and Aviva Burnstock, “Ageing and Deterioration of Traditional Oil and Tempera Paints,” in *The*

| Pigment | Photochemical degradation | Pigment-Medium Interactions | Accretions | Effects on Other Materials |
|--|----------------------------------|---|--|--|
| Azurite | None | Creates a greenish appearance owing to the darkening of the oil binding medium | None | None |
| Natural Ultramarine | None | Oxidative breakdown of the oil binding medium results in a stippled whitened surface | None | None |
| Indigo | Yes | None | None | None |
| Natural Organic Red Lakes (Madder, Carmine) | Yes | None | Surface crusts may form leading to a whitened/blanched surface | None |
| Green Earth | None | Physical degradation of the oil binding medium results in surface whitening (blanching) | None | None |
| Vermilion | Yes | Physical degradation of pigment takes place as a result of the breakdown of the binding medium | None | Accelerates the photo-oxidation of linseed oil films |
| Natural Organic Yellow Lakes (Weld) | Yes | None | Surface crusts may form leading to a whitened/blanched surface | None |
| Lead White | None | Saponification in oil may lead to lead soap aggregates, increased transparency, and surface whitening | None | None |
| Ivory (Bone) Black | None | None | None | Incompatible with lead based paints in oil media |

Appendix C: List of Materials and Their Definitions Used in the Copy and Original *Girl with a Pearl Earring*

Alkali Refined Linseed Oil

Conservation of Easel Paintings, ed. Joyce Hill Stoner et al. (New York: Routledge, 2012), 218-223.

Refined linseed oil purified with alkali instead of acid.⁷⁷

Azure (Azurite) Blue, Sennelier Extra-Fine Artists' Oils, PB15:4/PG7 in safflower oil
Azurite is made of basic copper carbonate. It is found in many parts of the world in the upper oxidized portions of copper ore deposits.⁷⁸

Brown Ocher, Sennelier Extra-Fine Artists' Oils, PY42/PW6/PR101/PG7 in safflower oil

Carbon Black, Sennelier Extra-Fine Artists' Oils, PBk8 in safflower oil
Most likely made from charred wood, or charcoal.⁷⁹

Crimson (Carmine) Lake, Sennelier Extra-Fine Artists' Oils, PR209 in safflower oil
Carmine can be made from kermes or cochineal. Kermes is one of the oldest organic colorants known and was used in ancient Egypt and the near East. Cochineal, native to the New World, was used by the Aztecs for dyeing and painting and was brought to Europe in the sixteenth century following the Spanish conquest. When hot aqueous extract of cochineal is precipitated with iron-free alum carmine lake is obtained.⁸⁰

Dammar Varnish

A resin varnish, gaining widespread use in the nineteenth century. Used to protect the paint layers. Dammar varnish retains its colorless appearance longer than any other varnish because the resin itself contains little or no coloring matter.⁸¹

French Ultramarine Blue, Grumbacher Artists' Oil Colors, Ultramarine Blue (PB29) in alkali refined linseed oil
Artificial ultramarine began to be commercially produced in 1830. The essential elements for its synthesis are sodium, aluminum, sulfur, and silica dioxide, and the raw materials for manufacture generally comprise anhydrous sodium sulfate and/or carbonate, china clay, silica (in the form of quartz or sand), and sulfur. The materials must have no traces of iron in them. The ingredients are finely ground, mixed, and heated in closed crucibles in a furnace at red heat for several hours in the absence of air. The product, after cooling, is a green mass known as green ultramarine or primary ultramarine. It is ground, washed

⁷⁷ Mayer, *The Artist's Handbook of Materials and Techniques*, 172.

⁷⁸ Rutherford J. Gettens and Elisabeth West Fitzhugh, "Azurite and Blue Verditer" in *Artists' Pigments: A Handbook of Their History and Characteristics*, Vol. 2, ed. Ashok Roy (Oxford: Oxford University Press, 1993), 23.

⁷⁹ Nicolas Eastaugh, Valentine Walsh, Tracey Chaplin and Ruth Siddall, ed. *The Pigment Compendium: A Dictionary of Historical Pigments* (Oxford: Elsevier Butterworth-Heinemann, 2004), 83.

⁸⁰ Helmut Schweppe and Heinz Roosen-Runge, "Carmine—Cochineal Carmine and Kermes Carmine," in *Artists' Pigments: A Handbook of Their History and Characteristics*, Vol. 1, ed. Robert L. Feller (Oxford: Oxford University Press, 1986), 264.

⁸¹ Mayer, *The Artist's Handbook of Materials and Techniques*, 222.

free of soluble salts, and dried. To convert it to the blue form it is reheated at about 500C. The final blue product is ground and washed free of soluble salts.⁸²

Indigo, Grumbacher Artists' Oil Colors, synthetic indigo (Vat Blue 1 Dye) in alkali refined linseed oil

A blue pigment as well as a major dye derived from the leaves of various *Indigofera* species native to India, South and Central America, and Asia.⁸³

Ivory (Bone) Black, Winsor & Newton Winton Oil Color, pure linseed oil and amorphous carbon produced by charred animal bones (PBk9)

A sub-category of carbon-based blacks. It is made from charred ivory and other animal bones. The inorganic, non-carbon, components are dissolved using a mineral acid such as hydrochloric acid, allowing a more intense black to be prepared.⁸⁴

Lead White

Until recently lead white was made by the "Dutch" or "stack" process. Metallic lead in the form of strips was exposed from one to three months in specially made clay pots, which had a separate compartment in the bottom to hold a weak solution of acetic acid (vinegar). The pots were stacked in tiers in a shed with fermenting horse manure or waste tan bark, which produced both heat and carbon dioxide. The combined action of acetic vapors, carbonic acid, and heat slowly transformed the exterior of the lead white to basic lead carbonate. The flaky product was scraped from the surface and after washing, drying, and screening was ground directly in oil.⁸⁵ Lead white was the only white pigment used in European easel painting until the nineteenth century.⁸⁶

Linseed Oil

Pressed from the ripe seeds of the flax plant, which is grown in all temperate or cold climates. The seed is crushed and the oil is extracted from it by pressing it in an expeller. The use of extreme pressure and heat is necessary, but the quality is inferior to that extracted by cold pressing with less pressure.⁸⁷

Livos Thinner

⁸² Joyce Plesters, "Ultramarine Blue, Natural and Artificial" In *Artists' Pigments: A Handbook of Their History and Characteristics*, Vol. 2, ed. Ashok Roy (Oxford: Oxford University Press, 1993), 56.

⁸³ Eastaugh, Walsh, Chaplin and Siddall, ed. *The Pigment Compendium*, 194.

⁸⁴ Ibid, 84.

⁸⁵ Rutherford J. Gettens, Hermann Kuhn and W.T. Chase, "Lead White." in *Artists' Pigments: A Handbook of Their History and Characteristics*, Vol. 2, ed. Ashok Roy (Oxford: Oxford University Press, 1993) 68.

⁸⁶ Ibid, 69.

⁸⁷ Mayer, *The Artist's Handbook of Materials and Techniques*, 170.

A thinner reduces the thickness of a paint or varnish so that it can be easily applied to the surface in a thin layer.⁸⁸ Thinners do not have any binding or film-producing qualities, though they do help the paint or varnish dry faster by allowing it to be spread in a thinner layer and a greater surface area exposed to the air.⁸⁹

Poppy Oil

A naturally colorless to straw-colored oil with none of the characteristic golden or amber color of linseed.⁹⁰

Red Ocher, Sennelier Extra-Fine Artists' Oils, PR101/PR102 in safflower oil

Forms in the oxidized, weathered portions of iron-rich mineral deposits, especially those associated with volcanic rocks.⁹¹

Refined Linseed Oil

Hot-pressed linseed oil that is further refined. It is mixed with sulfuric acid and water. Any traces of sulfuric acid and water are removed.⁹²

Rose Madder, Grumbacher Artists' Colors, Monoazo Yellow, Anthraquinone, (PY3)(PR83) in alkali refined linseed oil

A manufacturing variant of madder lake produced by selective extraction and deposition of pseudopurpurin, an anthraquinone compound present in the dyestuff extracted from the Rubiaceae species of plants.⁹³

Safflower Oil

Obtained from the seeds of *Carthamus tinctorius* and *C. oxyacantha*, plants which have been extensively cultivated in India, East Africa, Egypt, Turkey, and elsewhere. It is a fair replacement for linseed oil in artists' colors but its resistance to embrittlement is not equal to that of linseed oil.⁹⁴

Stand Oil, Richeson Oil Mediums: The Shiva Series

Stand oil is made from linseed oil heated to 535-575F for a few hours. Stand oil is a heavy, thick material about the same consistency as honey. It may be thinned to a painting consistency by mixing it with several parts of turpentine. Owing to its viscosity and its low acid value, it is not a suitable vehicle for grinding pigments, but when diluted with thinner it is one of the most useful ingredients of glazing or painting mediums. Stand oil dries to a smooth enamel-like film, free from brush marks, and it imparts this ability to paints when it is added to them.⁹⁵

⁸⁸ Ibid, 401.

⁸⁹ Ibid, 403.

⁹⁰ Ibid, 175.

⁹¹ Eastaugh, Walsh, Chaplin and Siddall, ed. *The Pigment Compendium*, 320.

⁹² Mayer, *The Artist's Handbook of Materials and Techniques*, 171.

⁹³ Eastaugh, Walsh, Chaplin and Siddall, ed. *The Pigment Compendium*, 325.

⁹⁴ Mayer, *The Artist's Handbook of Materials and Techniques*, 177.

⁹⁵ Ibid, 172.

Tinuvin 292

Titanium White (soft formula) Grumbacher Artists' Colors, (PW6)(PW4) in poppy seed and sunflower oil

Refers to any white pigment containing titanium and was not used until the twentieth century.⁹⁶

Turpentine

Made by distilling the thick resinous sap of pine trees and of similar coniferous trees in various parts of the world. Originally the entire crude exudation or oleoresin was known as turpentine. Later the volatile distillate was called 'spirits of turpentine' and 'oil of turpentine'. The resinous portion left after the turpentine is distilled is called rosin. The modern meaning of the term dates from the early part of the nineteenth century and now refers specifically to the distilled product. In Venetian turpentine, turpentine still means the entire oleoresin.⁹⁷

Ultramarine Blue

Made from the stone lapis lazuli, which contains the blue mineral lazurite, which is an essential part of the pigment.⁹⁸ In the past the main source of the mineral was in Afghanistan and was probably imported into Europe mainly by way of Venice.⁹⁹ The ground up mineral was incorporated into a mixture of melted wax, resins, and oils and the molten mass, usually wrapped in a cloth, kneaded under a dilute solution of lye. Blue particles of lazurite were washed out by this process and are collected by settling at the bottom of the vessel, while most of the colorless crystalline material and other impurities remain behind in the doughy mass. The largest and deepest colored blue particles emerge first and it was usual to carry out at least three separate extractions by this means, collecting several grades of pigment of diminishing quality. However carefully the extraction is carried out, some natural impurities, notably calcite, still seem to remain in the pigment, and these serve to distinguish the natural from the synthetic product.¹⁰⁰

Venetian Turpentine, Sennelier

Venetian turpentine is an exudation from the Austrian larch.¹⁰¹ In this case, turpentine means the entire crude oleoresin extracted from the tree before it is distilled, unlike the modern meaning of the word, which refers specifically to the distilled product.¹⁰²

Vermilion, Sennelier Extra-Fine Artists' Oils, PO73/PR254/PY1:1 in safflower oil

⁹⁶ Eastaugh, Walsh, Chaplin and Siddall, ed. *The Pigment Compendium*, 366.

⁹⁷ Mayer, *The Artist's Handbook of Materials and Techniques*, 404.

⁹⁸ Plesters, "Ultramarine Blue, Natural and Artificial," 37.

⁹⁹ Ibid, 38.

¹⁰⁰ Ibid, 39.

¹⁰¹ Mayer, *The Artist's Handbook of Materials and Techniques*, 239.

¹⁰² Ibid, 404.

Vermillion is the standard name in England and the United States given to the red artists' pigment based on artificially made mercuric sulfide (cinnabar).¹⁰³ The Dutch method of synthesizing vermilion consists of one hundred parts by weight mercury combined in an iron pan with twenty parts of molten sulfur to form black amorphous mercuric sulfide. The black mass, after pulverizing, was slowly charged into an earthenware retort where it was heated to above 580C when it would sublime and condense in earthenware pots or iron cylinders, being converted in the process to vermilion. It was then treated with a strong alkali solution to remove extra sulfur, washed, and then ground under water to prepare it as a pigment.¹⁰⁴

Yellow Lake (Weld), Sennelier Extra-Fine Artists' Oils, PY13/PBr23 in safflower oil

Used as a substitute for weld, which was originally used by Vermeer. Weld is a natural yellow dyestuff, obtained from the cultivated herbaceous plant Dyer's Rocket. It is the oldest European dyestuff and the oldest yellow dye plant in the world. Weld was used for dyeing silk and woolen materials as well as for making paints. For use in painting, the dye must be insoluble. Weld is soluble in oil and therefore must be precipitated onto a substrate.¹⁰⁵

Yellow Ocher, Grumbacher Artists' Colors, yellow oxide, natural iron oxide in alkali refined linseed oil

A naturally occurring earth pigment formed either as the direct weathering of iron-rich ore deposits or as soils, concentrating iron for underlying bedrocks.¹⁰⁶

Zinc White, Grumbacher Artists' Oil Colors, zinc oxide in alkali refined linseed oil

Zinc(II) oxide has been known since ancient times as a by-product of brass production in which copper and zinc carbonate were smelted. However, it was not widely used as a pigment until the end of the eighteenth century when alternatives were being sought to replace toxic lead white.¹⁰⁷

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¹⁰³ Rutherford J. Gettens, Robert L. Feller, and W.T. Chase, "Vermilion and Cinnabar" in *Artists' Pigments: A Handbook of Their History and Characteristics*, Vol. 2, ed. Ashok Roy (Oxford: Oxford University Press, 1993), 159

¹⁰⁴ Ibid, 162.

¹⁰⁵ Groen, Van der Werf, Jan van Den Berg, and Boon, "Scientific Examination of Vermeer's *Girl with a Pearl Earring*," 173.

¹⁰⁶ Eastaugh, Walsh, Chaplin and Siddall, ed. *The Pigment Compendium*, 401.

¹⁰⁷ Ibid, 407.

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